Autonomous Lunar Lander Development

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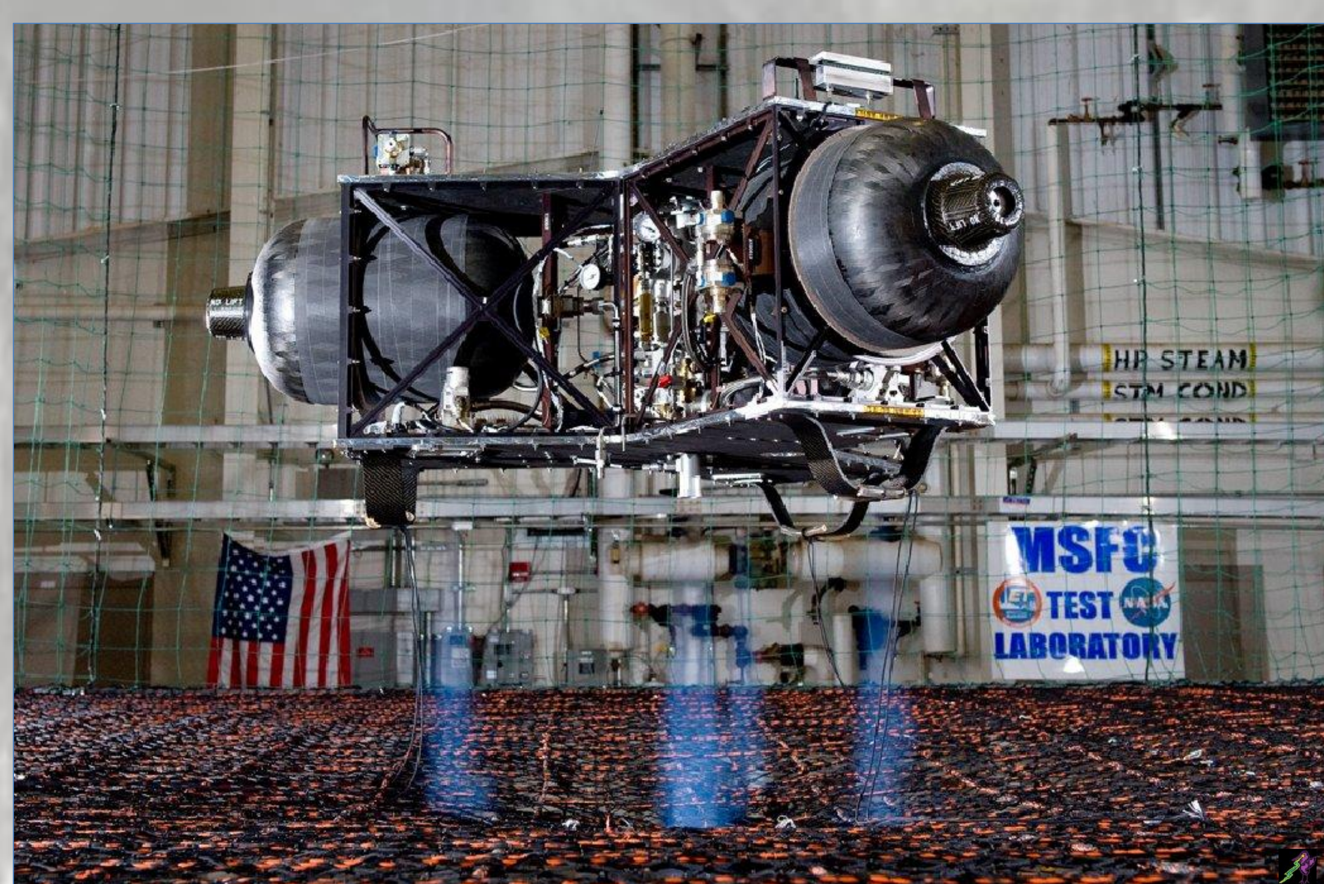
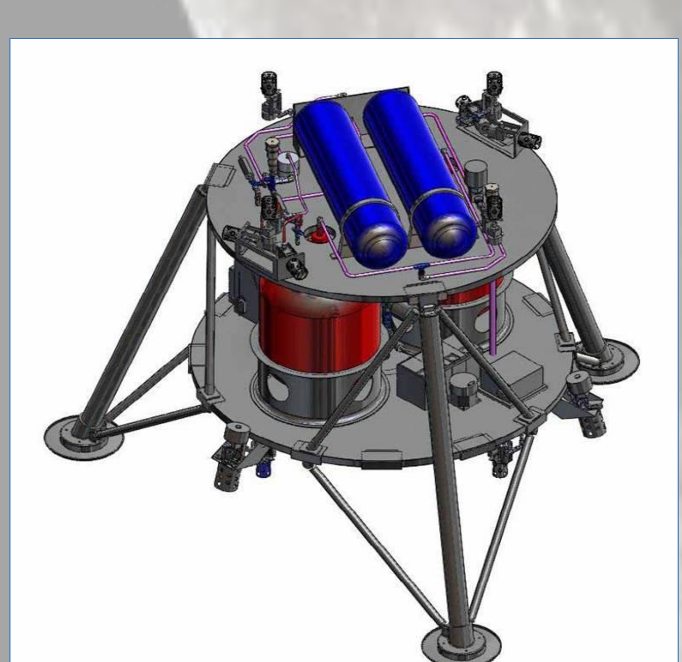
Background

A soft Lunar landing (fully controlled descent) has not been attempted by the United States in over three decades, since the last Apollo mission in 1972. In order to regain this important technical capability the Von Braun Center for Science and Innovation (VSCI) is collaborating with the Marshall Space Flight Center to validate the technologies and algorithms necessary for a robotic Lunar Lander capable of a powered descent. A testing facility has been established at the NASA Materials Environmental Test Complex (METCO) and a proof-of-concept vehicle was developed using compressed air as a propellant.



Cold-Fire Test Vehicle at the METCO

A more flight-realistic propellant, Hydrogen Peroxide (90% H_2O_2), was chosen for the second design iteration known as the Warm Gas Test Article (WGTA). This design has driven more stringent safety procedures, higher fidelity systems, and careful material selection. The propulsion system consists of a 12 thruster Attitude Control System (ACS), 3 descent thrusters and 1 Earth Gravity Compensator (EGC). The EGC will provide a variable thrust, offsetting 5/6th of the WGTA weight, simulating Lunar gravity conditions.

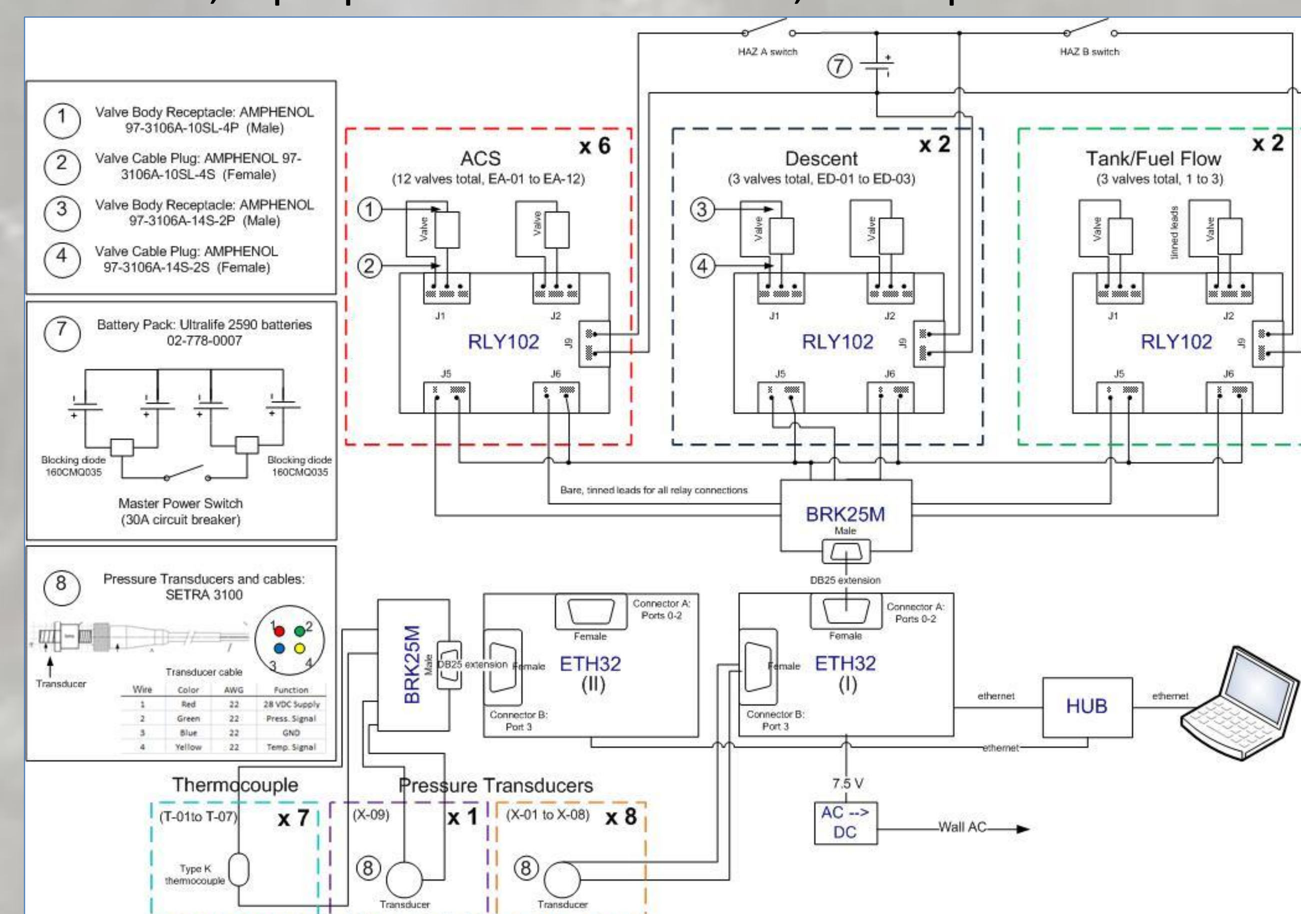


Warm Gas Test Article: Isometric View

Warm Gas Test Article: Propulsion System

Propulsion System Testing: Hardware Integration

A testing platform for the WGTA propulsion system was designed. An I/O board was interfaced with an array of digital relays which in turn were coupled to the 19 valves comprising the propulsion assembly: 16 thruster valves, 1 propellant loading/vent valve, 1 propellant isolation valve, and 1 pressurant isolation valve.

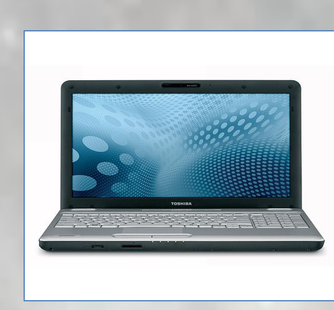


Test System Schematic

The propulsion system is being developed by Dynetics under a contract with VCSI. Key questions to be answered by testing:

- Is there enough H_2O_2 on board for a 45-60 second flight?
- Can the system flow rate meet the thruster demands?

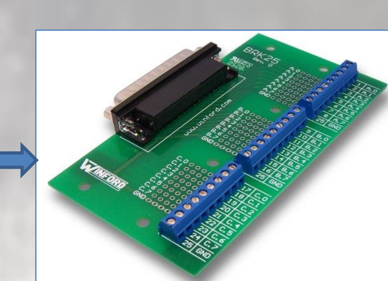
Information Flow



Computer

Wireless Router

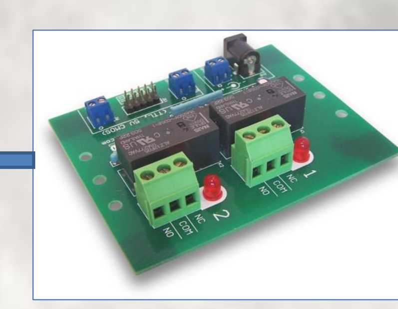
Eth32 I/O Board



DB25 Breakout Board

Thruster

Valve



Digital Relay

Real time test data was taken using 9 pressure transducers and 7 type K thermocouples.

Pressure Transducers

Thermocouple

Sources and Acknowledgements

Background image courtesy of NASA

VSCI.org

Special thanks to Marty Kress, Rob Franklin, Scott Gilley, and Dr. Frank Six

Propulsion System Testing: Software Development

Software was developed, using C#, to communicate with the I/O board and provide the functionality to manually actuate each valve, as well as autonomously execute a full flight profile. A full profile would last 45-60 seconds and exercise all ACS, descent, and EGC thrusters.

Screenshot of GUI for Propulsion Testing Software

The propulsion test graphical user interface (GUI) allows the user to:

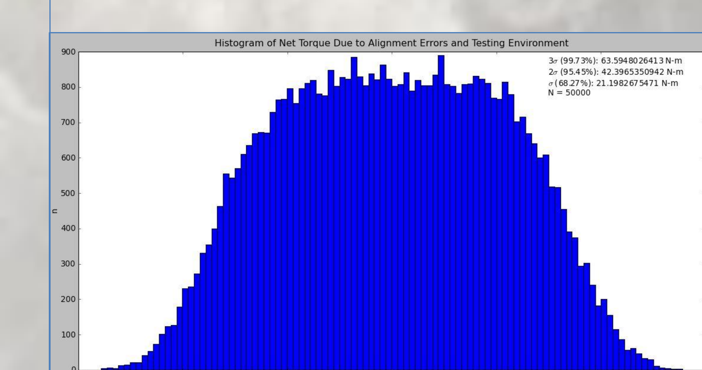
- See the status (open/closed) of each valve
- Manually actuate any valve
- Monitor the pressure and temperature readings

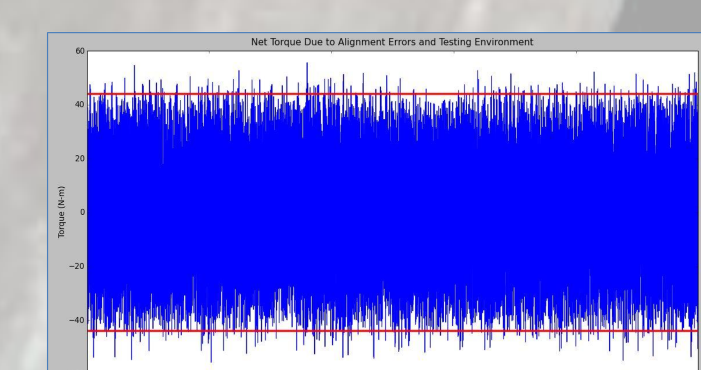
Additionally, the GUI:

- Logs all test data at 50 Hz
- Loads and executes automated flight profiles
- Automatically monitors pressure and temperature readings to ensure safe operating conditions

ACS Torque Budget Analysis

The ACS was designed with a small control margin. Unintended offsets or misalignments of the thrusters will cause significant torques that must be overcome in order to achieve flight stability. Additionally, factors such as wind, propellant slosh and unequal tank drain rates can add to the instability.





A Monte Carlo simulation was written, using Python, to determine the statistical effect of these torques. A uniformly random distribution was assigned to each possible torque source and the aggregate effect after 50,000 trial runs was analyzed. The histogram on the left shows the torque error distribution. Multiples of the standard deviation will be used to determine the fidelity of the control system, and the mechanical tolerances required for the Lander assembly.